REMARKS

The specification has been amended to specify patent numbers for previously listed applications, including the parent of this application. It is appreciatively noted that the Examiner has acknowledged Applicant's claim to domestic priority to a provisional application. Applicant also claims priority under 35 USC 120 to the parent application.

As required by the Examiner, the Abstract of the Disclosure has been rewritten as a single paragraph.

The non-elected claims 17 to 22, which were withdrawn from consideration based on the restriction requirement, have been canceled, and the non-elected claim 8 has also been withdrawn from consideration based on the restriction requirement, without prejudice to the right of Applicant to file a divisional application directed to the non-elected claims 8 and 17 to 22 and subject to the reinstatement of claim 8 if claim 1 is allowed. Independent Claim 23, and claims 24 to 28 dependent thereon, are newly submitted with this Amendment. Support for the recitations in newly submitted claim 27 may be found in the sentence which spans pages 46 and 47 of the specification. Support for the recitations in the other newly submitted claims may be found in claims 1 to 4 and 6, as filed. Since the number of newly submitted claims is equal to the number of claims canceled, and since this Amendment results in 3 independent claims, no additional claim fees are occasioned by this Amendment.

Independent claims 1 and 9 have been rejected under 35 USC 103(a) as not being patentable over U.S. patent 5,355,040 to New in view of U.S. patent Eakman et al, the Examiner stating that it would not have been unobvious to use the foil bearing as taught by Eakman et al in the apparatus of New for the purpose of reducing wear. The remaining pending dependent claims have also been rejected over these two patents either by themselves or in

combination with another reference.

Claims 1 and 9 have been amended to more clearly define what Applicant regards as the invention. As amended, claim 1 recites means for sharing load between said foil and magnetic bearings at rotor operating speeds. As amended, claim 9 recites effecting sharing of rotor load at rotor operating speeds between a foil bearing and a magnetic bearing. Support therefor may be found in the full paragraph on page 15 of the specification. For the reasons provided hereinafter, it is respectfully submitted that each of the claims, as amended and as newly submitted, is unobvious over the references of record and therefore patentable.

The present invention is directed to a hybrid magnetic and foil bearing. While it is a desirable benefit that one of the bearings may act as a back-up to the other, that is not the primary purpose of the present invention. Instead, the present invention is directed to an apparatus and method of sharing or allocating load between magnetic and foil bearings at rotor operating speeds. A hybrid bearing is considered desirable for various reasons as discussed on pages 3 to 6 of the specification.

A major problem in providing a workable hybrid bearing has been the differences in eccentricity between the foil and magnetic bearing parts in a journal bearing. Thus, the natural rotational center of a rotor within a magnetic bearing is different from the natural rotational center of a rotor within a foil bearing, and this difference, which changes as rotor speed changes, would seem to rule out a hybrid magnetic and foil bearing. See page 6, lines 23 to 32, of the specification. Also see the paragraph which spans pages 17 and 18 of the specification and FIGS. 3 and 4 of the drawings wherein it is illustrated that the locus of the magnetic bearing always remains at the geometric center 92, but the locus of the foil bearing

varies with load, as illustrated by loci 100. This problem is also discussed at col. 2, lines 44 to 57, of Eakman et al (one of the patents cited against the claims) as follows:

> In addition, the air bearings and the magnetic bearings will tend to 'fight' each other when the shaft is rotating. The hydrodynamic forces in an air bearing cause the shaft to rotate eccentrically with respect to the geometric center of the bearing. While the magnetic bearings are maintaining the shaft on or near the predetermined axis of rotation, the hydrodynamic forces in the air bearings attempt to move the shaft eccentric to the axis of rotation. This difference in operating characteristics results in significant power loss in the machine. In summary, the difficulties of integrating the dimensional and operational characteristics of air bearings and magnetic bearings have prevented the use of air bearings as backup for magnetic bearings.

The present invention goes beyond merely providing "air bearings" as backup for magnetic bearings but also provides for allocation or sharing of load between them at rotor operating speeds.

A method of sharing load is illustrated in Figs. 2, 3, 4, and 8 wherein a supervising controller makes a series of calculations and effects suitable adjustments to achieve the desired trajectory at various rotor spin speeds. However, such a method using a calculated trajectory is time-consuming, and there may not be sufficient time for the bearing to await the calculated trajectory input at any given rotor spin speed. Load-sharing is achieved in accordance with the present invention in such a way as to avoid the use of time-consuming use of calculations of rotor trajectory at various rotor spin speeds so that the load-sharing can be conducted on the fly.

In order to conduct the load-sharing with such desired quickness, in accordance with the present invention, the time-consuming use of the rotor trajectory calculations based on rotor spin speeds is discarded, and the actual load is inputted to a controller, which can then more quickly and robustly and precisely allocate this actual load to the foil and magnetic bearings (without having to calculate trajectories based on rotor spin speeds) at the respective spin speed. Thus, as discussed on pages 43 and 44 of the specification and illustrated in FIG. 22 of the drawings, the sensed load is inputted to a load sharing controller 1042 via line 1044. Based on the value of the actual load inputted to the load controller, signals are outputted from the load controller via lines 1046 and 1048 to controller inputs 1034 and 1036 respectively to shift the set points, i.e., to effect shifting of the rotor upwardly or downwardly to take more or less of the load and thus control the sharing of the load between the magnetic and foil bearings at various rotor operating speeds.

As indicated in the full paragraph on page 47 of the specification, "actual load" is limited to those measurements of bearing condition which are proportional to bearing load, for example, applied flux, bearing strain, bearing temperature, acceleration, or bearing component deformations. "Actual load" of course does not include rotor position or spin speed (which is what the calculations of FIG. 8 are based upon) or change in magnetic bearing gap width. Thus, without the necessity of the calculations of FIG. 8, the allocation of load at any given load by using actual load input can be done more quickly and directly.

New discloses a magnetic bearing back-up wherein a pressurized fluid (such as a gas) is supplied to the suspension gap between the moving magnetic bearing armature and stationary armature pole faces. A magnet control means is responsive to a

decrease in gap width below an acceptable minimum to supply the fluid to the gap to form a hydrostatic bearing between the stationary and movable armatures to aid or replace the magnetic bearing support. As seen in FIGS. 5 and 6 thereof, the rotatable armature and the pole faces of the stationary armature carry a layer of low-friction material to enable the surfaces to contact without damage, "at least at low speeds." The fluid is supplied through an aperture in the layer. The control valve for the fluid is under the control of a back-up control which is connected to the magnet control means to receive signals indicative of the inability of the magnet control means being able to support the shaft within the predetermined range of operational shaft positions dispersed by the suspension gap.

Unlike the present invention, New does not teach or suggest the use of a foil bearing with the magnetic bearing or the use of a bearing for sharing load with the magnetic bearing at rotor operating speeds.

The condition sensed by the magnet control of New is magnetic bearing gap width, which is not proportional to load and therefore does not constitute a means for sensing actual load. Thus, New also does not teach or suggest means for sensing actual load on a bearing, as provided by the present invention.

Eakman et al discloses a backup bearing for magnetic bearing to support a rotating shaft in the event that the magnetic bearings fail due to the loss of electric power. The backup bearing includes a housing and a fluid film bearing element which is adapted to passively float in the housing and with the shaft during normal operation of the magnetic bearings and which is adapted to support the rotating shaft on a film of fluid if the magnetic bearings fail. In the embodiment of FIG. 8 thereof, the back-up bearing is configured as a foil bearing which includes generally rectangular foils made from thin resilient material and

formed with a slight curvature and spaced circumferentially around a generally cylindrical inner surface of a bearing housing member with one end of each foil secured to the surface. The secured foils extend circumferentially and overlie one or more adjacent foils.

Unlike the present invention, Eakman et al does not teach or suggest the use of a bearing for sharing load with the magnetic bearing at rotor operating speeds. Neither does Eakman et al teach or suggest means for sensing actual load on a bearing, as provided by the present invention.

Since neither New or Eakman et al teaches or suggests the use of a bearing for sharing load with a magnetic bearing at rotor operating speeds or means for sensing actual load on a bearing, as provided by the present invention, the combination of New and Eakman et al would still not result in the present invention.

Moreover, as indicated by the previously discussed and quoted passage at col. 2, lines 44 to 57, of Eakman et al, Eakman et al does not disclose any idea as to how to effect load-sharing at operating speeds between a foil and a magnetic bearing. Neither does New disclose any idea as to how to achieve such load-sharing. Both New and Eakman et al were content to merely provide backup means for a magnetic bearing.

Neither New or Eakman et al or any other of the references of record, whether taken together or individually, discloses, teaches, or suggests means for sharing load between foil and magnetic bearings at rotor operating speeds, which comprises a controller, means for sensing actual load on at least one of the foil and magnetic bearings, and means for inputting the sensed actual load to said controller for effecting the allocation of load between said foil and magnetic bearings at respective rotor operating speeds, as claimed in claim 1, as amended, in order to

achieve such load-sharing quickly and robustly and precisely. Therefore, it is respectfully submitted that claim 1, as amended, is unobvious over the prior art and therefore patentable.

Neither New or Eakman et al or any other of the references of record, whether taken together or individually, discloses, teaches, or suggests a method for bearing a rotor wherein rotor load is shared at rotor operating speeds between a foil bearing and a magnetic bearing, including sensing actual load on at least one of the foil bearing and the magnetic bearing, and inputting the sensed actual load to a controller for effecting the allocation of load between the foil bearing and the magnetic bearing at respective rotor operating speeds, as claimed in claim 9, as amended, in order to achieve such load-sharing quickly and robustly and precisely. Therefore, it is respectfully submitted that claim 9, as amended, is unobvious over the prior art and therefore patentable.

Neither New or Eakman et al or any other of the references of record, whether taken together or individually, discloses, teaches, or suggests structure for sharing load between foil and magnetic bearings at rotor operating speeds, which comprises a controller, a sensor for sensing actual load on at least one of the foil and magnetic bearings, and the sensed actual load being inputable to said controller for effecting the allocation of load between said foil and magnetic bearings at respective rotor operating speeds, as claimed in newly submitted claim 23, in order to achieve such load-sharing quickly and robustly and precisely. Therefore, it is respectfully submitted that newly submitted claim 23 is unobvious over the prior art and therefore patentable.

Since each of the remaining claims pending in this application is dependent on one or the other of claims 1, 9, and 23, as amended and as newly submitted, it is respectfully

submitted that they are also patentable for at least the same reasons. Since claim 1, as amended, has been shown to be patentable, it is respectfully requested that the withdrawn non-elected claim 8, dependent on claim 1, as amended, be reinstated and allowed.

Since each of the claims, as amended and as newly submitted, pending in this application has been shown to be patentable, it is respectfully submitted that this application is in condition for allowance, and such is respectfully requested.

Respectfully submitted,

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Enclosure: Petition and fee for Extension of Time

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